NJDOT Bureau of Research

QUARTERLY PROGRESS REPORT

Project Title:	Reclaimed Asphalt Pavement In Hot Mix Asphalt
RFP NUMBER: 2009-01	**NJDOT RESEARCH PROJECT MANAGER**: Edward S. Kondrath
TASK ORDER NUMBER: 16	**PRINCIPAL INVESTIGATOR:** Yusuf Mehta, Ph.D., P.E. Rowan University
Project Starting Date: 1/1/2009 **Original Project Ending Date**:12/31/2010	**Period Starting Date**: April 1, 2009 **Period Ending Date**: June 30, 2009

Task	**% of Total**	**% of Task this quarter**	**% of Task to date**	**% of Total Complete**
1. Comprehensive Literature Review	15	100	15	15
2. Assessment of the Variability of RAP Stockpiles in NJ	5	60	3	3
3. Sensitivity Analysis	20	0	0	0
4. Verification of Blending Charts	20	0	0	0
5. Evaluation of Laboratory Mixture Performance	20	0	0	0
6. Evaluation of Impact of Poor Quality Control Procedures	10	0	0	0
7. Conduct Life-Cycle Cost Analysis of Flexible Pavements with RAP	5	0	0	0
8. Final Report	5	0	0	0
TOTAL	100			18

RECLAIMED ASPHALT PAVEMENT IN HOT MIX ASPHALT

SECOND QUARTERLY PROGRESS REPORT – APRIL 01-JUNE 30 2009

BACKGROUND

Recycling of old asphalt pavement is an environmentally friendly, cost effective recycling method. Presently the state of New Jersey allows 15% reclaimed asphalt pavement (RAP) surface course mixes This research project will evaluate the possibility of using higher percentages of RAP in HMA. In the second quarter of the project a literature review of feasibility of WMA in RAP mix, plant surveys and the development of a grading system and additional analysis and experiments were carried out. This quarterly report gives the details of the tasks performed during this second quarter of the project. In addition to the completion of the research tasks, the graduate students in the research team participated in prestigious Sigma Xi poster competition held at Saint Joseph University on April 17th 2009 and the undergraduate students won the second place at the New Jersey Water Environment Association on May 13th 2009.

RESEARCH TASK

This section provides an update of each task.

TASK 1 – COMPREHENSIVE LITERATURE REVIEW

As discussed in the first quarterly report most of the researchers had observed that with the increase in the RAP content fatigue resistance of the RAP mix reduces. Also, increased stiffness caused by RAP binder results into poor workability and compaction. A feasible solution to this problem may be to use Warm Mix Asphalt (WMA) in the RAP mix. Detailed literature review of the effect of the WMA on RAP mix is provided in Appendix A1.

TASK 2. - SURVEY AND GRADING SYSTEM FOR VARIABILITY WITHIN RAP STOCKPILES

This section is a continuation of a section from the first quarterly report. In the first quarterly report a detailed survey of two plants were carried out. After that the research team had visited three different plants. Summary of plant visit and summary of findings of all plant visits are in Appendix B1.

In addition to the plant survey, a grading system was developed to rate the plant. This was described in *Appendix B2 of the first quarterly report*. This grading system would depend upon the variability observed within the RAP stockpile. The rating of a plant will be dependent on factors such as the standard error of the measured asphalt content, measured moisture content, the true grade of the recovered binder and the sizes of the aggregate on selected sieve sizes. For this grading system evaluation of binder characteristic of binder recovered from RAP stockpile has been carried out. Appendix B2 gives detailed information about the sampling, the testing procedure and the results.

Standard testing procedures used for testing are attached in Appendix B3. Standard procedures sheet used are

1. AMRL sheet for extraction recovery.
2. AMRL sheet for binder grading
3. Modified AASHTO T319 procedure.

ADDITIONAL TASKS

In addition to the proposed tasks, the research team also carried out some analysis and experiments to evaluate plant variability and blending of RAP mixes. To evaluate the plant and material variability of RAP mix, analysis of quality control (QC) data of recently constructed projects was carried out. The most of the QC data in this report was obtained from NJDOT's Central regional offices. In this analysis mix parameters such as air void measurements from gyratory compactor at the plant, asphalt content, moisture content, VMA, D/B ratio were studied for different percentage of RAP content. Detailed description of the analysis is provided in the Appendix C1.

The research team also conducted a mini-study on coating to determine an estimate on the working binder in the RAP mix. In this mini-study, mechanical mixing was used to determine how much RAP binder coats the virgin aggregate. The details of the study are presented in Appendix C2.

In addition to above analysis and experiment, a literature review on fractionation of RAP in plants was carried out. After visiting different plants and studying different types of plant operation the research team decided to explore fractionation of RAP in the plant. Fractionation of RAP will be the possible solution to RAP variability and will help in increasing the RAP content in the RAP mix. The different plant operations that are typically observed were mapped with the plant visited. In the next quarter, the research team will be visiting the plant presently doing fractionation. Detail of the fractionation is in the Appendix C3.

PROPOSED ACTIVITIES FOR NEXT QUARTER BY TASK

- ✓ Evaluating binder characteristic, moisture content and gradation of RAP sample from various plants and reporting.
- ✓ Preparing RAP mixes for 15, 30 and 50% RAP content with PG70-22 and PG72-22.

- ✓ Additional proposed tasks for the next quarter are also presented at the end of the Appendices.

LIST OF DELIVERABLES PROVIDED IN THIS QUARTER BY TASK

- ✓ Task 1

- Appendix A1: Effect of WMA on RAP mix.

- ✓ Task 2

- Appendix B1: RAP plant survey
- Appendix B2: Characterizing binder from the Stockpile samples
- Appendix B3:
  AMRL sheet for extraction recovery
  AMRL sheet for gradation
  AASHTO T 319

- ✓ Additional work

- Appendix C1 - Analysis of QC data
- Appendix C2 – RAP coating study
- Appendix C3 :Fractionation

PROGRESS ON IMPLEMENTATION AND TRAINING ACTIVITIES

Not scheduled

PROBLEMS/PROPOSED SOLUTIONS

Not scheduled

Total Project Budget	272,453
Total Project Expenditure to date	49,401
% of Total Project Task completed	18%

EFFECT OF WMA ON RAP MIX

RAP with HMA mixes are difficult to design and construct due to RAP's aged and stiffened binders. This causes problems with workability and compatibility of the RAP mix because appropriate temperature during mixing and compaction need to be selected which is high enough to get off the moisture from the aggregate and low enough to avoid stiffening of aged binder in RAP (Mingjiang Tao 2008).

Warm mix asphalt (WMA) technologies may provide a feasible solution to the above problem due to their capability of reducing asphalt viscosity at relatively lower construction temperatures. This is asserted by Mallick (2007) in one of his laboratory study that the use of Sasobit (one of the WMA technologies) with RAP enabled the production of HMA at 125^0C with properties comparable to those of HMA produced at 150^0C. Also Mallick (2008) in another study confirmed the possibility to produce HMA mixes with 75% RAP and 1.5% Sasobit H8 at 125^0C, which has similar air voids as mix (produced with extracted aggregates, virgin stones and sand, and standard PG 64-28 at 150^0C).

Mingjiang Tao 2008 utilized the torque tester to determine that the WMA produced using Sasobit H8 and Advera zeolite helps in lowering the viscosity of the mixtures made from 100% RAP, thus improving workability at temperatures as low as 110^0C. It was also observed by Mingjiang (2008) that Sasobit H8 and Advera zeolite have a stiffening effect at low temperatures which resulted in higher values of seismic modulus and indirect tensile strength. From the above observation it is clear that WMA additives not only reduces the compaction temperature and increase the workability but also helps in low temperature performance.

Two demonstration projects using Sasobit WMA technology was conducted by Maryland State Highway Administration in 2005. In this study, 35 and 45% RAP were used in surface and base course layers, respectively with 1.5% Sasobit (by weight of binder) (Advanced Asphalt Technologies 2005). When these samples were compared to the HMA control sections with the same amount of RAP without Sasobit; it was observed that the use of Sasobit achieved better workability and compaction, improved the resistance to moisture damage of marginally moisture sensitive mixture. It also resulted in a net savings of $4.55/ton by switching from 25% RAP to 45% RAP with the WMA additive WMA studies conducted at the National Center of Asphalt Technology (NCAT), Hurley and Prowell (2006) also observed that the addition of WMA additives (Sasobit, Aspha- Min zeolite, and Evotherm) lowered the measured air voids compared to that of the respective control mixtures at the same PG binder.

Therefore, the limited studies presented above appear to indicate that WMA technology has the potential to limit the problems of cracking associated with stiffening of HMA due to high percentage of RAP.

REFERENCES

Hurley, G., and Prowell, B. (2006). “Evaluation of Potential Processes for Use in Warm Mix Asphalt” *Journal of the Association of Asphalt Paving Technologists*.

Lauren Swett, Rajib B. Mallick and Dana Humphrey (2007). “A Study of Temperature and Traffic Load Related Response in Different Layers in an Instrumented Flexible Pavement” *International Journal of Pavement Engineering*.

Mallick, R., Kandhal, P., and Bradbury, R. (2008) “Using Warm Mix Asphalt Technology to Incorporate High Percentage Reclaimed Asphalt Pavement (RAP) Material in Asphalt Mixtures” *Transportation Research Board: Journal of the Transportation Research Board*.

Mingjiang Tao (2009). “An Evaluation of the Effects of Warm Mix Asphalt Additives on Workability and Mechanical Properties of Reclaimed Asphalt Pavement (RAP) Material” *88th Transportation Research Board Annual Meeting*, Washington D.C.

Wielinski, Hand and Rausch (2009). “Laboratory and Field Evaluations of Foamed Warm Mix Asphalt Projects” *88th Transportation Research Board Annual Meeting*, Washington D.C.

APPENDIX B1

RAP PLANT SURVEY

FIGURE

TABLE

INTRODUCTION

This section is a continuation of the section “Survey and grading system for variability within RAP stockpile” of the first quarterly report. In the second quarter, the project research team has visited three different plants named as plant E, F and G (real names of the plants are kept confidential). During the plant visit RAP samples were collected from three different locations, the detailed sampling procedure is described in the Appendix B2. Survey questions from the standard survey sheet (Appendix B1 of first quarterly report) were asked. The summary of the survey is as follows.

PLANT E

On April 6, 2009 the research team visited plant E. Plant E’s testing lab is equipped with four NCAT ovens, two pyro clean ovens and two gyratory compactors (one mobile - used in emergency). QC Manager of the plant had provided information about moisture content of RAP stockpile. She had stated that moisture content in the RAP stockpile is similar to that of the coarse sand stockpile and hence approximate moisture content for given rainfall can be determined. Figure 1 below shows moisture content at three different layer of RAP stockpile for 24 hrs after 2” rain. The detailed survey of the plant E is tabulated below (Table 1):

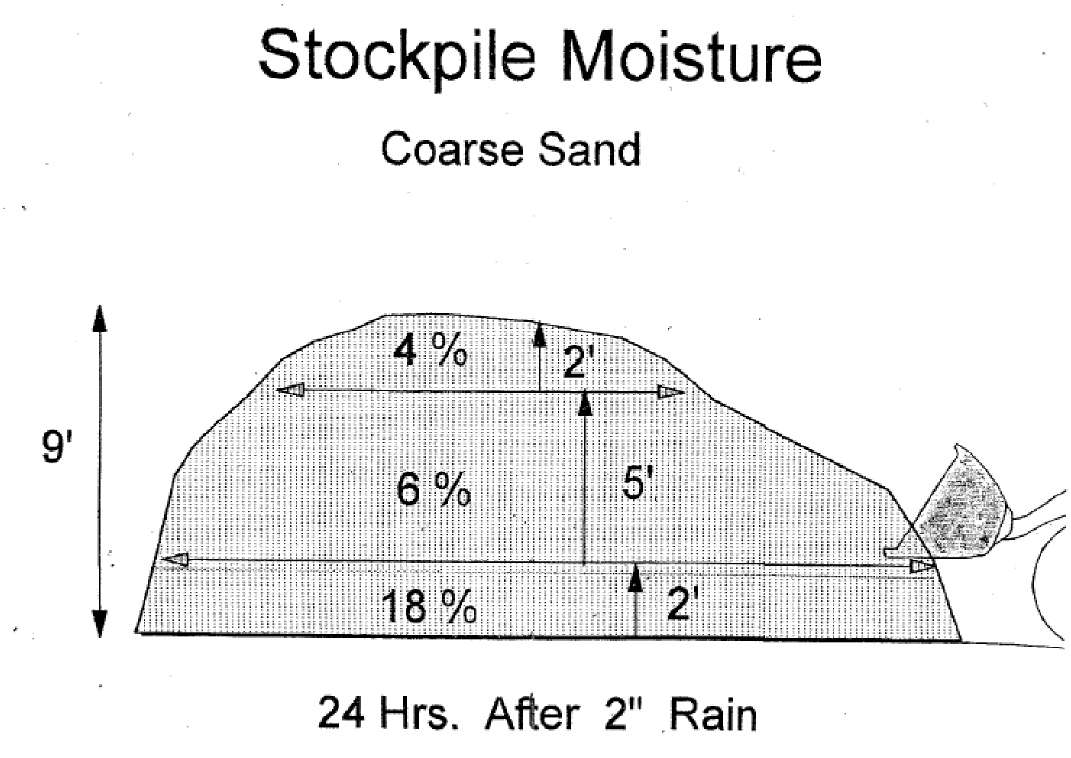

FIGURE 1. STOCKPILE MOISTURE (PLANT E)

TABLE 1. PLANT SURVEY DETAIL FOR PLANT E

Number of workers on site	50 – 99
Number of lab technicians	5
Type of Plant	Continuous
Continuous Entry	Behind burner
On Site Lab Facility	Yes
On –Site Lab testing	Only Mixture Testing/No binder Testing
No of Cold feed bins	1
Annual Tonnage of RAP (thousand)	200-399
Height of Tallest RAP stockpile	More than 50 ft
Type of Storage of Pile	Single stockpile
Stockpile Drainage to prevent segregation	Sufficient
Method to determine Asphalt Content	Ignition Method
Type of RAP	Crushed
Size of Crushed RAP	< 0.5 inches (Working on pilot project to fractionate and make ½" - #4 and minus #4 product)
Quality Control Test performed on field	Ignition Oven Moisture Content Gradation

PLANT F

On May 12, 2009 research team has visited plant F. At the plant, RAP is stored into three sizes, - minus 3/8, 1/2, and 1 inch. This plant has an arrangement of processing two different size of RAP in the mix at one time but currently only minus 3/8 size of RAP is used. The plant has capacity of producing 500 ton HMA/hr. Plant F is also involved in production of warm mix asphalt. The detailed survey of the plant F is tabulated below (Table 2)

TABLE 2. PLANT SURVEY DETAIL FOR PLANT F

Number of workers on site	50 – 99
Number of lab technicians	1 to 5 (2)
Type of Plant	Continuous
Batch Entry	Continuous
Continuous Entry	Behind burner
On Site Lab Facility	Yes
On –Site Lab testing	Only Mixture Testing/No binder Testing
No of Cold feed bins	2
Annual Tonnage of RAP (thousand)	< 199
Height of Tallest RAP stockpile	>11 ft
Type of Storage of Pile	Separate stockpile
Stockpile Drainage to prevent segregation	Sufficient
Method to determine Asphalt Content	Ignition Method
Type of RAP	Crushed
Size of Crushed RAP	-3/8,-1/2,-1inch
Quality Control Test performed on field	Ignition Oven Moisture Content Gradation

PLANT G

On May 28, 2009 research team has visited plant G. Plant G's onsite testing lab is equipped with NCAT ovens, pyro clean ovens and gyrator compactors. Plant G has two stockpiles, larger stockpile is used for base layer and small stockpile is used for surface layer HMA. Stockpile is in unprocessed (uncrushed) condition and processed only on demand. As per plant operator, plant has capacity of producing 400 ton/hr. He also mentioned that introduction of 15% RAP reduces the temperature by 70 to 80^{0}F which consumes additional fuel. The detailed survey of the plant G is tabulated below (Table 3)

TABLE 3. PLANT SURVEY DETAIL FOR PLANT G

Number of workers on site	0 to 49
Number of lab technicians	1 to 5
Type of Plant	Continuous and Batch
Batch Entry	Continuous and batch
Continuous Entry	Behind burner
Batch Entry	Weigh Hopper
On Site Lab Facility	Yes
On –Site Lab testing	Only Mixture Testing
No of Cold feed bins	1
Annual Tonnage of RAP (thousand)	60 to 70
Height of Tallest RAP stockpile	Greater than 11 ft
Type of Storage of Pile	Single stockpile
Stockpile Drainage to prevent segregation	Sufficient
Method to determine Asphalt Content	Ignition Method
Type of RAP	Crushed
Size of Crushed RAP	-1½” and -½”
Quality Control Test performed on field	Ignition Oven Moisture Content Gradation They used to do extraction recovery some year ago.

SUMMARY OF FINDING

Table 4 gives the summary of all the plants. From this table it can be seen that 60% of the plants have both type of plant setup, i.e. batch and drum (continuous) plant setup. Selection of plant is depended upon the tonnage produced. For large quantity of HMA drum plant is generally used. . In approximately 80% of drum plants, RAP is introduced behind the burner, where showering flights are absent. This arrangement of flights prevents generation of blue smoke. Blue smoke is generated when RAP directly come in contact with the burner. Approximately 60% plants have two cold feed bins. Availability of multiple bins might be useful in using different sieve sizes of RAP. Approximately 40% of plants have separate stockpile which may help reduce the variability of RAP. There are some features which are common in all plants like onsite mixture testing facility, drainage availability, and use of crushed RAP.

TABLE 4. SUMMARY TABLE FOR PLANT SURVEY

Id. No.	A	B	E	F	G
Number of workers on site	50-99	100-150	50 – 99	50 – 99	0 to 49
Number of lab technicians	6-10	6-10	5	1 to 5 (2)	1 to 5
Type of Plant	Continuous and Batch	Continuous and Batch	Continuous	Continuous	Continuous and Batch
Continuous Entry	Behind burner	Mid Drum	Behind burner	Behind burner	Behind burner
Batch plant Entry	Hot elevator	Hot elevator	-	-	Weigh Hopper
On Site Lab Facility	Yes	Yes	Yes	Yes	Yes
On –Site Lab testing	Only Mixture Testing	Only Mixture Testing	Only Mixture Testing	Only Mixture Testing	Only Mixture Testing
No of Cold feed bins	2	2	1	2	1
Annual Tonnage of RAP (thousand)	<199	As per demand	200-399	< 199	60 to 70
Height of Tallest RAP stockpile	>11 ft	11ft	More than 50 ft	>11 ft	>11 ft
Type of Storage of Pile	Single pile	Separated Pile	Single stockpile	Separate stockpile	Single stockpile
Type of pile storage area	-	Sloped Surface	-	-	-

Stockpile Drainage to prevent segregation	Sufficient	Sufficient	Sufficient	Sufficient	Sufficient
Method to determine Asphalt Content	Ignition Method	Ignition Method	Ignition Method	Ignition Method	Ignition Method
Type of RAP	Crushed	Crushed	Crushed	Crushed	Crushed
Size of Crushed RAP	0.5 inch	0.5- 0.75 inches	< 0.5 inches (Working on pilot project to fractionate and make ½" - #4 and minus #4 product.)	-3/8,-1/2,-1inch	-1½" and -½"
Quality Control Test performed on field	Ignition Oven Moisture Content Gradation	Ignition Oven Fines Correction Moisture Content Gradation	Ignition Oven Moisture Content Gradation	Ignition Oven Moisture Content Gradation	Ignition Oven Moisture Content Gradation They used to do extraction recovery some year ago.

CHARACTERIZING BINDER FROM STOCKPILE SAMPLES

Table of Content

FIGURES

TABLES

INTRODUCTION

The variability of the RAP stockpile must be quantified for the use of high RAP in the mixture. The variability depends on the standard error of the recovered asphalt content, moisture content, the true grade of the recovered binder and the sizes of the aggregate on selected sieve sizes. The following section describes sampling, testing methods and results of the experiments performed to quantify the variability.

SAMPLING PROTOCOL

The RAP samples were collected from the different plants in the following manner. Three RAP samples were collected at the base of the stock pile. An effort was made to have the samples equidistant from each other. The fourth sample was the mixture of the three samples.

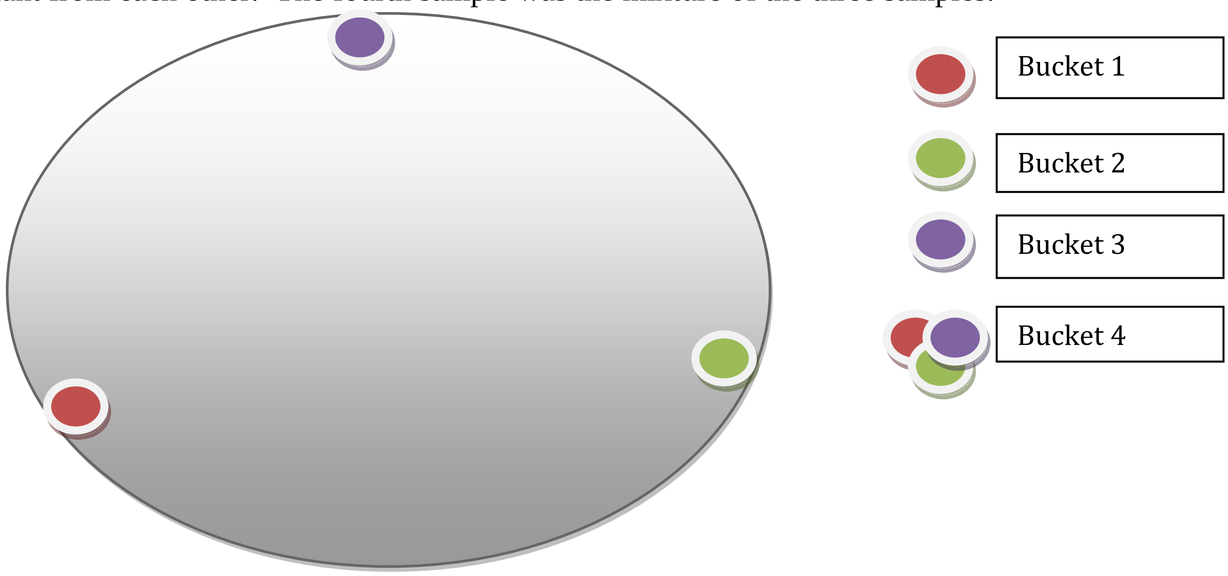

FIGURE 2. STOCKPILE LAYOUT TO EXPLAIN SAMPLING METHOD

The above mentioned sampling protocol was selected to capture the variability of the RAP samples within the stockpile. The initial plan was to rate the plant on the basis of the variability of binder properties and the gradation of RAP. In the proposal, the following table was presented that described the testing matrices to compare four plants.

TABLE 5. TESTING MATRIX IN THE PROPOSAL (NUMBERS INDICATE REPLICATES)

Plant	Gradation of RAP	Moisture Content	Extraction and Recovery (T319)	Binder Characterization (M320)
Plant 1	3	3	3	3
Plant 2	3	3	3	3
Plant 3	3	3	3	3
Plant 4	3	3	3	3

The research team later determined that the proposed testing protocol would not be sufficient to capture the variability accurately. Therefore, eventually the research team changed their plan as per following specifications (**Error! Reference source not found.**).

TABLE 6. TESTING MATRIX (NUMBERS INDICATE REPLICATES) (2 REPLICATES FROM EACH BUCKET 2*4=8)

Plant	Gradation of RAP	Moisture Content	Extraction and Recovery (T319)	Binder Characterization (M320)
Plant A	8	8	8	8
Plant B	8	8	8	8
Plant C	8	8	8	8
Plant D	8	8	8	8
Plant F	8	8	8	8

This change in the plan is adopted to account for the variability of the RAP sample even within the stockpile. Performing these tests will give us more precise results on how a sample varies within the stockpile.

The extraction and recovery (ER) is a very cumbersome process and because of which it was necessary to not only perform this process accurately, but also to obtain maximum binder content without altering the properties. The research team tried a couple of practice samples before actually performing the proposed testing plan. This helped the team to fine-tune the procedure. The research team initially performed the ER experiments following AASHTO T319 procedure. **Error! Reference source not found.** shown below is the extraction vessel used to perform the Extraction by AASHTO T319 (modified SHRP).

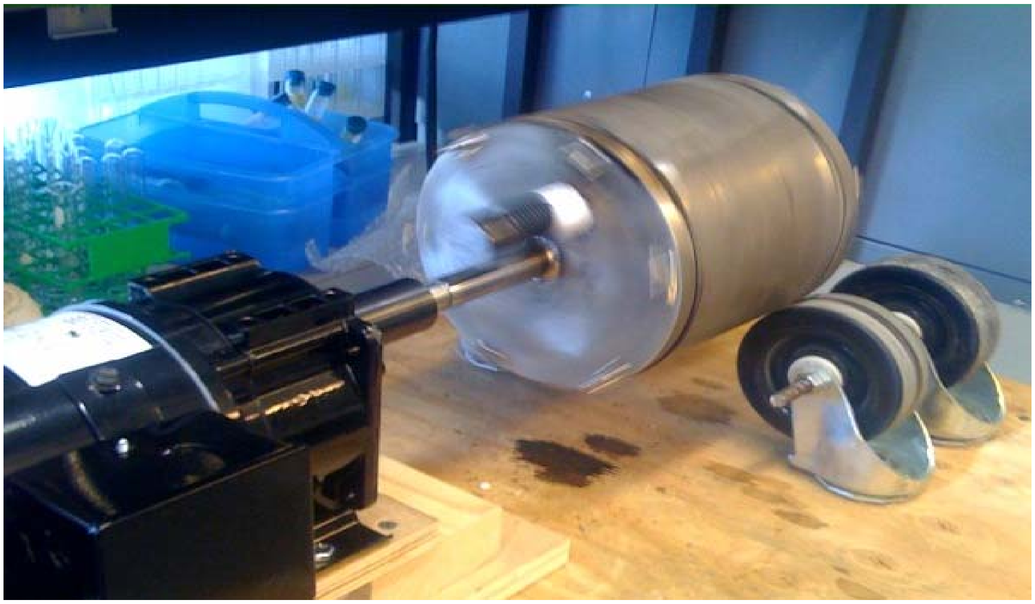

FIGURE 3. EXTRACTION METHOD BY AASHTO T319 METHOD

Eventually the research team realized it was very tedious procedure and very difficult to accurately perform especially extraction procedure because of the clogging of the filter by the fines. Peterson et al. 1999 also observed similar phenomenon. The **Error! Reference source not found.** displayed below shows the clogging of fines between the filters.

FIGURE 4. CLOGGING OF FINES BETWEEN THE FILTERS IN T319 EXTRACTION METHOD.

To overcome the above problem of clogging of fines, the research team decided to try another extraction method. AASHTO T164 (Method A) which is very similar to the above method. AASTHO T164 (Method A) of extraction is also called as the centrifuge method. **Error! Reference source not found.** shown below is the model use to perform extraction by T164

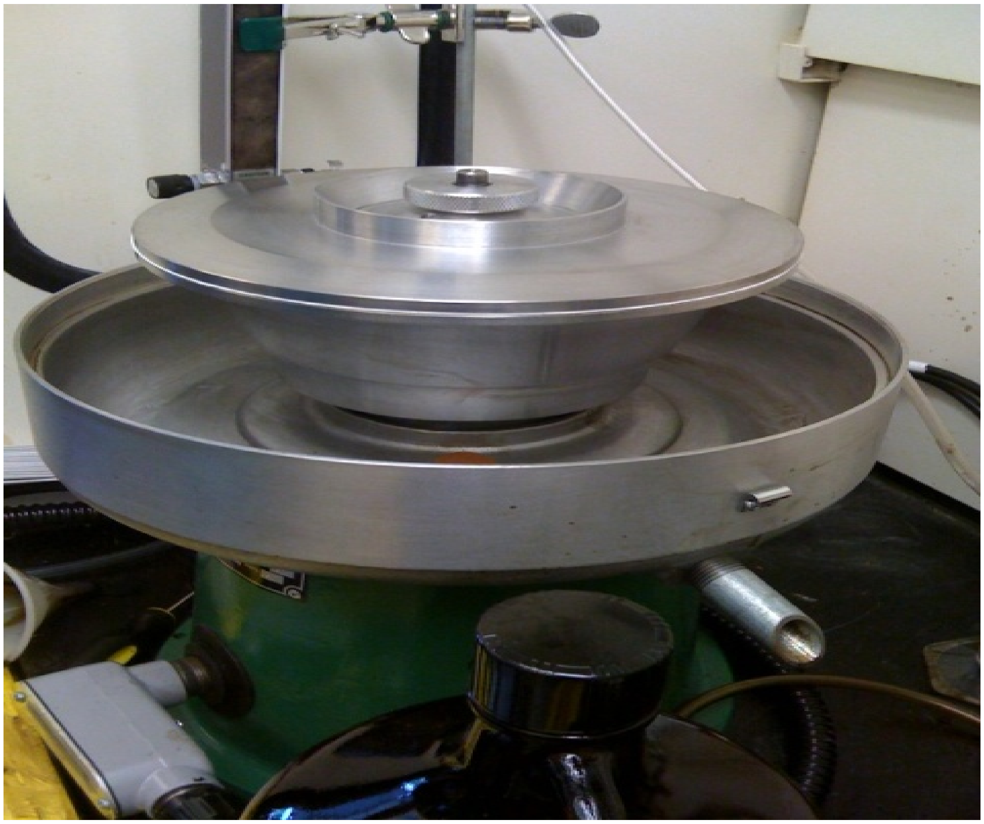

FIGURE 5. EXTRACTION METHOD BY AASHTO T164/ASTM D5404.

The advantage of this method is that it not only requires less time to extract, but also allows for larger volume of sample to be extracted and there is no clogging of the fines. This lead the team to combine both the procedures to expedite the experiment and reduce errors.

The new experimental procedure checklist was developed combining the AASHTO T164 for extraction and the AASHTO T319 for the recovery procedure as attached in (Appendix B3). Once the research team was comfortable to perform the above procedure accurately, another combination of extraction and recovery was also tried by the research team. This combination included an extraction and recovery by AASHTO T 164/ ASTM D 5404. This method also gave accurate results of binder content as the previous combination did, and this method took almost half of the time to perform than the previous one did. Therefore, the research team revised the test matrix again and compared the difference in the properties of the binder extracted from the two procedures. **Error! Reference source not found.** below shows the testing matrix of the experiments using different ER procedures.

TABLE 7. TESTING MATRIX (NUMBERS INDICATE REPLICATES) (2 REPLICATES FROM EACH BUCKETS 2*4=8).

Plant	Extraction (ASTM 5404) & Recovery (AASHTO T319)			Extraction (ASTM 5404) & Recovery (ASTM 5404)			Binder Characterization (M 320)
	Binder Content	Moisture Content	Gradation of RAP	Binder Content	Moisture Content	Gradation of RAP	
Plant A	8	8	8	8	8	8	16
Plant F	8	8	8	8	8	8	16

The above matrix was developed to compare two different methods of recovery procedures (**AASHTO T319 and ASTM D5404**) but keeping the same extraction procedure (**AASHTO T164/ASTM 5404**). The properties of the binder recovered from both the procedures are to be compared. This comparison will help to suggest which recovery procedure is better in terms of giving replicate results, time consumed to perform the entire procedure, and recovering binder from the RAP with unaltered properties.

The following **Error! Reference source not found.** displays the results of the binder content recovered from the Plant A. Both samples were taken from the Bucket Number 4 (mixed bucket). The binder was recovered with two different recovery procedures as explained above and the results of the recovered binder and the moisture content of both have been displayed in **Error! Reference source not found.**.

TABLE 8. RESULTS OF % MOISTURE CONTENT AND % BINDER RECOVERED BY TWO DIFFERENT RECOVERY METHODS.

Plant	Code	Recovery Method	Binder Recovered (%)	Moisture Content (%)
Plant F	4F051209#1	AASHTO T 319	4.57	4.54
Plant F	4F051209#2	ASTM D 5404	4.53	4.45

The recovered binder is then tested for PG Grade and the results of the binder testing for both the samples have been displayed in

TABLE 9. AVERAGE RESULTS OF BINDER TESTING FOR BINDER RECOVERED WITH TWO DIFFERENT RECOVERY METHODS.

	Codes	4F051209#1	4F051209#2
G*/sin (δ) (min 1.00 kPa)	Unaged DSR @ 82^{0}C (KPa)	8.20	8.09
	Unaged DSR @ 94^{0}C (KPa)	2.45	2.31
G*/sin (δ) (min 1.00 kPa)	RTFO DSR @ 82^{0}C (KPa)	20.29	12.16
	RTFO DSR @ 94^{0}C (KPa)	6.44	3.64
G*sin (δ) (max 5000 kPa)	RTFO+PAV DSR @ 51^{0}C (KPa)	858.07	685.79
BBR Data	Stiffness for 60s @ -12^{0}C (MPa)	239	289
	Stiffness for 60s @-6^{0}C (MPa)	131	150
	m-value for 60s @-12^{0}C	0.25	0.25
	m-value for 60s @-6^{0}C	0.28	0.28
PG Grade		**96.96-10.75**	**96.02-11.71**

DISCUSSION

Based on the limited testing conducted so far, the results in **Error! Reference source not found.** appear to indicate that the percent binders recovered from the different recovery procedures are similar. The PG Superpave properties are similar for both the cases, except for stiffness at high temperature of RTFO DSR samples. However, the PG grades of the binders are similar.

FUTURE WORK

The plan is to compare the results of the binder content recovered by the different recovery procedures and the binder properties of the recovered RAP binder of two different plants. The samples will be taken from the Bucket No 4 (Mixed Bucket). The **Error! Reference source not found.** shows the future testing matrix of the experiments using different ER procedures.

TABLE 10. FUTURE TESTING MATRIX (NUMBERS INDICATE REPLICATES).

Plant	Extraction (T164/ASTM 5404) & Recovery (AASHTO T319)			Extraction (T164/ASTM 5404) & Recovery (ASTM 5404)			Binder Characterization (M320)
	Binder Content	Moisture Content	Gradation of RAP	Binder Content	Moisture Content	Gradation of RAP	
Plant F	2	2	2	2	2	2	4
Plant A	2	2	2	2	2	2	4

The above matrix is design to compare the results of binder content and binder properties due to different recovery procedures. This would help to select a particular procedure to perform should extraction and recovery experiments need to be performed on a larger scale. This selection would be done on the basis of the time consumed to perform the experiment, properties of the recovered binder and the complexity of the procedure.

Eventually the plan is to do the variability study within the stockpile for all the plants with one of the selected Recovery procedures from the above conditions. The matrix for the same would be planned with the consent of NJDOT.

REFERENCES

AASHTO Standard T 319, 2008, “Standard Method of Test for Quantitative Extraction and Recovery of Asphalt Binder from Asphalt Mixtures,” www.transportation.org

ASTM Standard D5404, 2003, “Standard Practice for Recovery of Asphalt from Solution Using the Rotary Evaporator," ASTM International, West Conshohocken, PA, 2005, DOI: 10.1520/D5404-03, www.astm.org.

Peterson, R.L., H.R. Soleymani, R.M. Anderson, and R.S. McDaniel. “Recovery and Testing of RAP Binders from Recycled Asphalt Pavements.” Association of Asphalt Paving Technologies, 1999.

APPENDIX B3

MODIFIED AASHTO T319 PROCEDURE

Code	Technician :	Date:

Moisture Content (AASHTO T 329)	
Apparatus Check	
Oven, maintains 163 ± 14°C (325 ± 25°F)	
Sample container, of sufficient size to contain the sample without danger of spilling	
Balance, 2-kg (4.4-lb) capacity, readable to at least 0.1 g	
Test sample obtained by AASHTO T248, Method B (quartering)	
Sample placed into the container, distributed evenly	

Initial Sample Temp		^{o}C
Mass of empty pan M_p		gms
Mass of Initial Sample M_i > 1000gms		gms
Mass of Pan + Initial Sample (M_p +M_i) @ initial temp		gms
Keep the sample in the Oven for 90 mins at $163^{0}C$		
Mass of Pan + Sample after 90 min		gms
Mass of Pan + Sample after 30 min		gms
Mass of Pan + Sample after 30 min		gms
Mass of Pan + Sample after 30 min		gms
Let the sample dry down to initial temperature		
Mass of sample at initial temperature= M_f		
Mass of Pan + Sample after 30 min @ initial temp		gms
Mass of Final Sample M_f		gms
Moisture Content % $((M_i-M_f)/ M_i)* 100$		%

Notes:

Extraction and Recovery (AASHTO T164)						
Apparatus Check						
Reclaimed / reused solvents should not be used for testing.						
normal-Propyl Bromide, conforming to ASTM D6368						
Fume hood or effective surface exhaust system in a well-ventilated area						
Oven capable of maintaining 110 ± 5°C (230 ± 9°F) for warming sample						
Pan of appropriate size [ASTM: 12 x 8 x 1 in.]						
AASHTO only: Balance, readable to 0.1 % of sample mass, conforms to M231						
ASTM only: Balance: accuracy of at least 0.01 percent of sample mass = (0.15)						
Centrifuge Method						
Centrifuge capable of 3000 r/min or greater						
Continuous flow type						
Class G1 (0.01 g) balance available [ASTM: Class GP1]						
Centrifuge Extractor						
Aluminum bowl with cover						
Can be rotated at variable speeds up to 3600 r/min						
Apparatus set up safely (not prone to explosions and installed in fume hood)						
Filter rings, felt or paper, to fit rim of bowl						
Procedure						
If necessary, mixture warmed in pan at 230 ± 9°F (110 ± 5°C) until it can be handled						
Particles of mixture separated with spatula or trowel						
Sample obtained by splitting or quartering, conforms to minimum sample mass table below						
Table of minimum sample masses for T164/D2172 conforms to minimum sample mass						
Size in inches	No. 4	No. 8	1/2	3/4	1	1.5
Mass in Kg	0.5	1	1.5	2	3	4
Sample divided into equal portions for multiple extractions if necessary						
If necessary, test specimen for moisture determination obtained						

Mass of the Bowl		gms
Mass of the Bowl + Sample		gms
Mass of Initial RAP sample ~(1500gms) or (3000gms)		gms
Mass of dried filter (@110C until constant mass) before Extraction		gms
Mass of the empty receiving beaker before Extraction		gms
Mass of the empty filtration flask before Extraction		gms
Sample covered with solvent and allowed to disintegrate for not more than 1 hr		
Bowl with solvent and sample placed in extraction apparatus		
Dry filter ring fitted around edge of bowl and cover clamped tightly on bowl		
Centrifuge started revolving slowly and speed increased gradually Max speed <3600rpm		
1 minute for rest		
Centrifuge stopped and 200 mL or more of solvent added		
Centrifuge wash repeated until Last extract clear and not darker than light straw color		
Sample dried by the following method		
Bowl, aggregate, and filter ring dried to constant mass in an oven at 110 ± 5°C (230 ± 9°F)		
Mass of the filter after extraction		gms
Mass of the extracted aggregate (dry aggrgates + filter paper after extraction - initial mass of filter paper)		
Mass of th extracted Aggregate		gms
Mass of the receiving beaker after transfering the solution to the flask and letting the fumes evaporate		gms

Recovery Procedure ASHTO(D5404) & T319	
Recovery Apparatus	
Rotavapor apparatus	
Distillation flask, depth of approximately 40 mm (1.5 in) when fully immersed. flask having a 2000 mL capacity is recommended	
Variable speed motor, capable of rotating the distillation flask at least 50 rpm	
Condenser	
Solvent recovery flask	
Heated oil bath	
Angle of distillation flask from horizontal to bath is approx. 15 degrees	
Centrifuge apparatus	
Wide-mouth bottles, 250 to 500 mL capacity	
Manometer or vacuum gage, suitable for measuring the specified vacuum	
Gas flow meter, capable of indicating a gas flow of up to 1000 mL/min	
Sample container, having an adequate volume to hold the sample and added solvent	
Vacuum system, capable of maintaining a vacuum to within ± 0.7 kPa (± 5 mm Hg) of the desired level up to and including 80 kPa (600 mm Hg)	
Nitrogen gas or carbon dioxide gas	
Bath liquid	
Verify the Calibration of Oil bath in every 6 months as per T319 11.1	
Verify the Calibration of Vacuum indicator in every 6 months as per T319 11.2	
Verify the rotational velaocity of the rotary evaporator in every 6 months as per T319 11.3	
Verify the flow rate of th enitrogen flowmeter in every 6 months as per T319 11.4	
Solvent	
Normal Propyl Bromide (nPB)	
Solvents listed used only under a hood or with an effective exhaust system in a well ventilated area	

Recovery Procedure

Close the filter transfer line and distill solvent at 100 C (oil bath temperature) and a vacuum of 93.3 kPa		
Distill the contents of the recovery flask until it is about one-third full		
Mass of the centrifuge bottles NO 1 to 0.01gms		gms
Mass of the centrifuge bottles NO 2 to 0.01gms		
Mass of the centrifuge bottles NO 3 to 0.01gms		
Mass of the centrifuge bottles NO 4 to 0.01gms		gms
Pour the contents into the centrifuge bottles such that their masses are equal		
Increase th eoil Bath temperature to 174 C		
Centrifuge the bottles at 3600 rpm for 25 minutes		
Mass of the flask after transfering to distilation flask		gms
Re-start the ditsillation procedure at oil bath temperature of 174 C		
Continue the distillation till th econdensation rate falls below 1 drop in 30 seconds.		
Introduce nitrogen gas at a rate of 1000mL/ minute which reads as 62 on the flow meter reading		
Allow this for 30 minutes with the sufficient amout of vacuum on it		
Mass of the centrifuge bottles after centrifuge NO 1		gms
Mass of the centrifuge bottles after centrifuge NO 2		gms
Mass of the centrifuge bottles after centrifuge NO 3		
Mass of the centrifuge bottles after centrifuge NO 4		
Mass of the empty tin to collect binder (0.01) balance		gms
Mass of the tin + Binder recovered		gms
Mass of the binder recovered		gms

Calculation of Binder Content			
Amount of water in sample =	%moisture /100 * Mass of initial sample		gms
Aggregate mass after extraction =	(dry aggrgates + filter paper) after extraction - initial mass of filter paper		gms
Mass of fines =	Increase of mass of beaker, flask, and cntrifuge bottls		gms
Binder Content Calculated			gms
% Binder Content			%
Binder Content Actual			%

EVALUATION OF NJDOT QUALITY CONTROL DATA

Table of Content

FIGURES

TABLES

INTRODUCTION AND OBJECTIVE

In the laboratory, testing on a RAP mix is done under controlled conditions, which leads to repeatable results. On the other hand, at the plant where bulk production of hot mix asphalt (HMA) is done it is more difficult to get repeatable or consistent results. In other words, at the plant, in addition to the RAP material variability (as explained in the first quarterly report), construction variability also exist. Hence, it is required to analyze quality control data to capture both the components of variability. Assessment of the plant mix will give us information on how the critical parameters, such as air voids and dust to binder ratio, of HMA with high RAP vary during construction. In this analysis, plant inspection quality control data from four plants were chosen. They were obtained from the New Jersey department of transportation (NJDOT) regional offices. Names of the plants are kept confidential. The plants are identified with alphabet A, B and so on. Same plant with different RAP content is identified as A00 and A30 where A00 indicate plant A with 0% RAP and A30 indicates plant A with 30% RAP. Identification number, serial number for JMF and total number of test result assessed is shown in Table 1.

TABLE 11. PLANT DETAIL

Id. No.	**A30**	**B10**	**C00**	**D15**	**E15**
Serial No.	C35DC0190	C03BC0024	C40BC0327	C47DC0327	C44DS0246-15R
Total number of tests	192	26	21	6	30

In this analysis, five parameters chosen were moisture content (MC), asphalt content (AC), air void (AV) of the gyratory compacted specimen at the plant, dust to binder ratio (D/B ratio) and void in mineral aggregate (VMA). Reason behind choosing the above parameter are as follows;

- **MC** - In the plant, RAP is not directly exposed to the heat through burner, it is indirectly heated through hot virgin aggregate. The higher the moisture content, more heat will be taken away to dry the RAP rather than to keep the temperature high of the mix. If the moisture content is variable, it may lead to non-uniform mixture temperature and hence non-uniform compaction. Therefore, the variation of RAP moisture content on HMA was analyzed.
- **AC and AV –**

  Blending phenomenon in the RAP mix is still unknown. Type of blending (Total blending, partial blending or black rock effect) in the mixture helps to determine the amount of binder to be used in the mixture. In our analysis, trend of AC and AV for different percentage of RAP is plotted to evaluate their variability for different RAP content. Design binder content (DBC) in the JMF is determined by Superpave mix design. The binder content of HMA sample is determined by Ignition method.

- **D/B ratio and VMA –** RAP consist of RAP binder and RAP aggregate. RAP binder around the RAP aggregate also holds the fine materials. These fine materials get released when RAP aggregate is heated for preparing RAP mix. Increase in fine material in the mix reduces mix's resistance to rutting and fatigue, depending upon whether it acts as an extender or a filler. Quantifying the amount of fine materials from RAP in the mix before mixing is not possible. In our analysis D/B ratio and VMA for different RAP content is analyzed to find impact of high RAP on these two parameters. Formula for VMA is follows;

$$\mathrm{VMA} = \frac{\text{Volume of air void} + \text{Volume of effective asphalt binder}}{\text{Total volume of the mixture}} \text{ x } 100$$

The following section gives the comparison of MC, AC, AV, D/B ratio and VMA for the various plants.

ANALYSIS AND RESULT

MOISTURE CONTENT

Moisture content of A30 mix varies from 0.006% to 0.121% which is considered to be negligible. QC data of the other plant had negligible amount of moisture content.

ASPHALT CONTENT

Figure 6 and Figure 7 shows the variation of percentage of asphalt content by volume and weight with lot number for the various plants. Also, Table 2 gives the detail information of maximum, minimum and average amount of asphalt content for the various plants. From Table 2, it can be observed that standard deviation of asphalt content in high RAP (A30) was found to be the lower than others. Also, to capture the variation of asphalt content imaginary band of 0.6% (0.3% above and below the design mix design AC) AC was considered. AC of A30 plant was found to be less variable as only 20% of the test results were out of the range. This indicates that the AC content for high RAP content is not more variable than that of low RAP content.

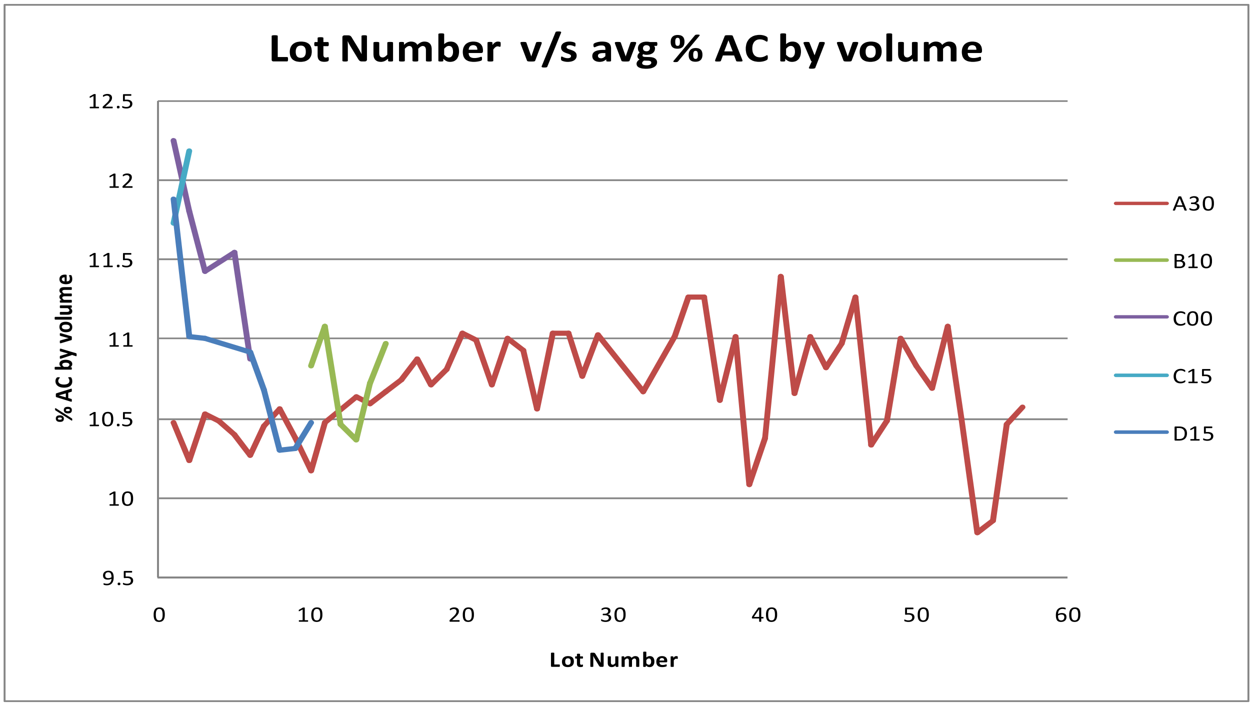

FIGURE 6. CHART SHOWING VARIATION OF LOT NUMBER VERSUS % ASPHALT CONTENT BY VOLUME FOR VARIOUS PLANTS.

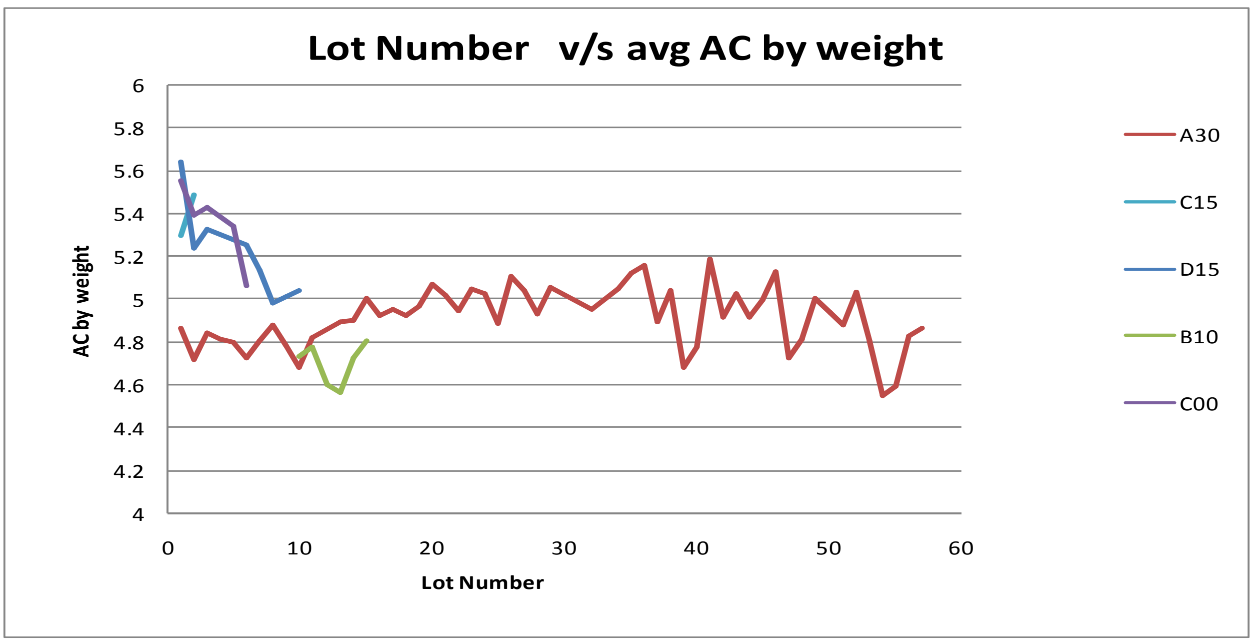

FIGURE 7. CHART SHOWING VARIATION OF LOT NUMBER VERSUS % ASPHALT CONTENT BY WEIGHT FOR VARIOUS PLANTS

TABLE 12. COMPARISON OF DETAILS OF PERCENTAGE OF ASPHALT CONTENT FOR VARIOUS PLANTS

Id No.	A30	B10	C00	C15	D15
% RAP	**30**	**10**	**0**	**15**	**15**
Maximum AC by volume (%)	11.83	11.55	12.58	12.18	12.89
Minimum AC by volume (%)	9.32	9.71	9.99	10.74	9.57
Average AC by volume (%)	10.69	10.74	11.58	11.95	10.82
Average Standard deviation for AC by volume	0.33	0.33	0.43	0.30	0.73
Maximum AC by weight (%)	5.44	5.03	5.96	5.49	6.06
Minimum AC by weight (%)	4.33	4.31	4.70	4.90	4.65
Average AC by weight (%)	4.91	4.70	5.36	5.40	5.20
Average Standard deviation for AC by weight	0.14	0.12	0.22	0.12	0.31
AC as per mix design (by weight) (%) (Assume X)	4.80	4.90	5.28	5.30	5.50
Number of tests results greater than (X+0.3)	34.00	0.00	5.00	0.00	3.00
% tests results greater than (X+0.3)	17.71	0.00	23.81	0.00	10.00
Number of tests results less than (X-0.3)	5.00	7.00	2.00	1.00	19.00
% tests results less than (X-0.3)	2.60	26.93	9.52	16.67	63.33

AIR VOID (AV)

Figure 8 shows the variation of average air void with lot number for various plants. Also, Table 3 gives detail information of maximum, minimum and average amount of air void for various plants. From the Table 3, it can be observed that standard deviation of AV for A30 plant was not the highest amongst the plant analyzed, which indicate that production of the high RAP content does not result into highly variable AV of gyratory compacted specimens.

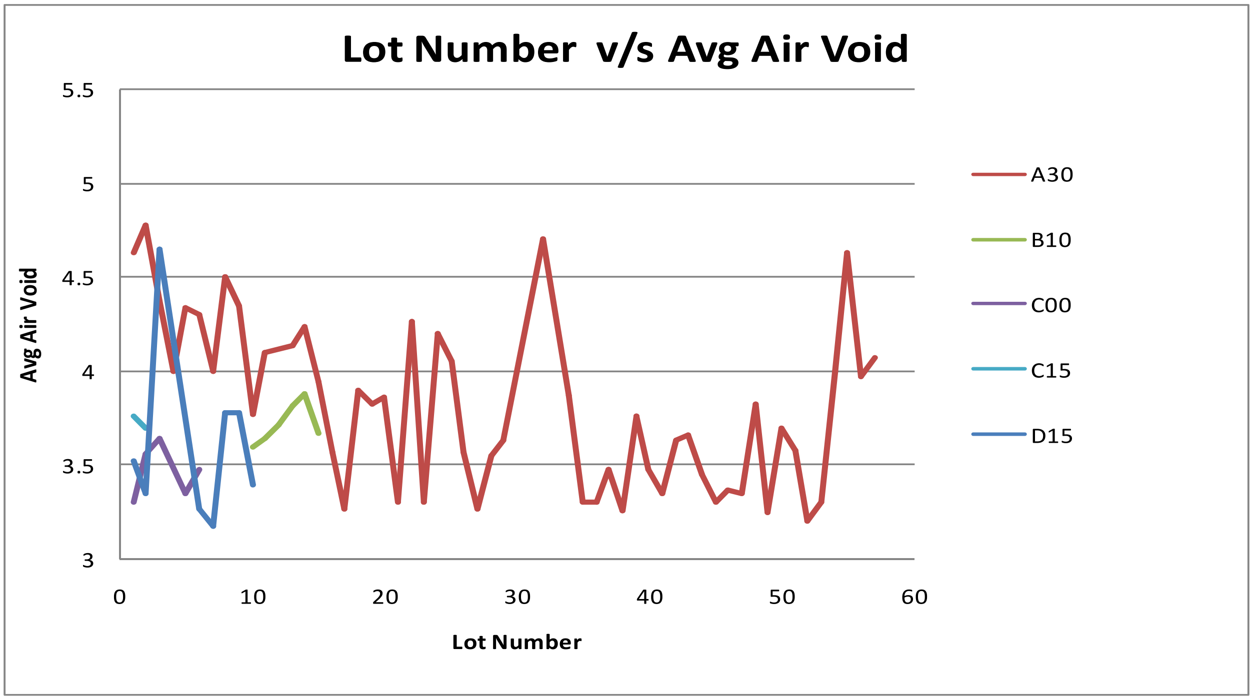

FIGURE 8. CHART SHOWING VARIATION OF LOT NUMBER VERSUS % AIR VOID FOR VARIOUS PLANTS

TABLE 13. COMPARISON OF DETAILS OF PERCENTAGE OF AIR VOID FOR VARIOUS PLANTS

Plant	A30	B10	C00	C15	D15
% RAP	**30**	**10**	**0**	**15**	**15**
Maximum AV (%)	5.40	4.80	4.10	4.90	4.70
Minimum AV (%)	3.00	3.10	3.10	3.30	2.90
Average AV by volume (%)	3.81	3.72	3.47	3.73	3.6
Average Standard deviation for AV	0.32	0.42	0.21	0.33	0.31

D/B RATIO

Figure 9 shows variation of dust to binder ratio with lot number for various plants. Also, Table 4 gives detail information of maximum, minimum and average amount of asphalt content for various plants. From the available data it can be observed that for A30 plant around 35% of test result had dust to binder ratio higher than 1.2, which is the higher limit for D/B ratio, as per NJDOT and Superpave specification. This indicates that with increase in the RAP content, the amount of fines in the mix increases.

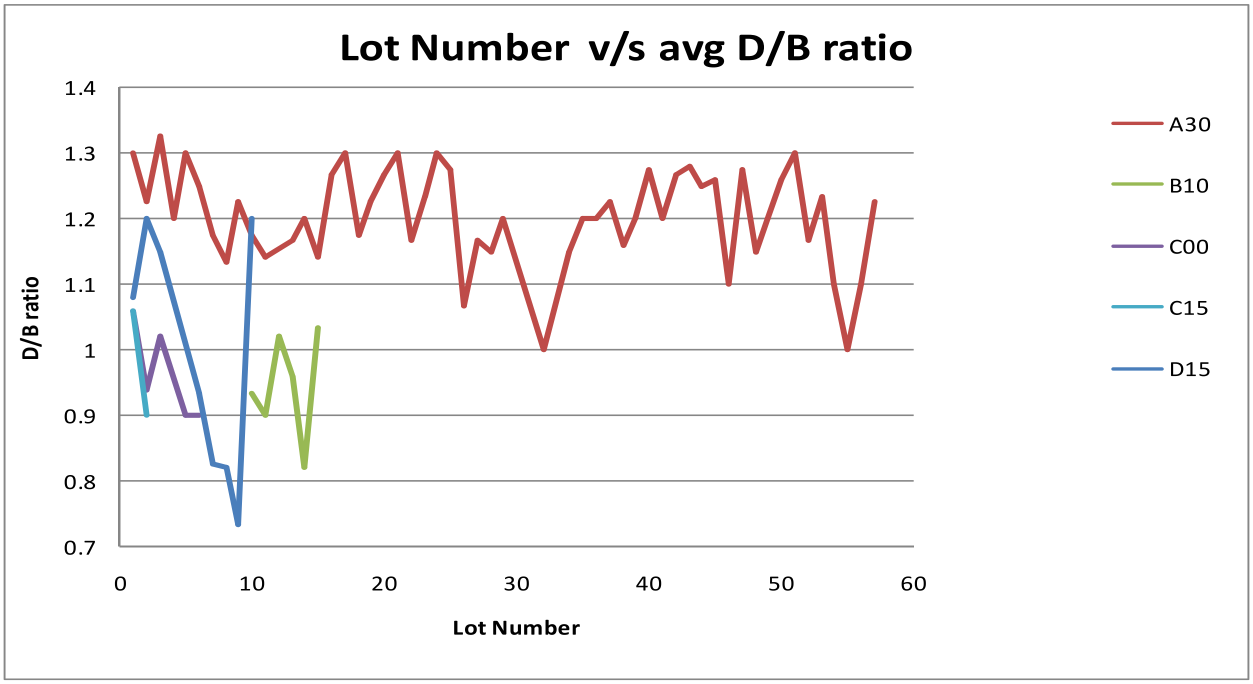

FIGURE 9. CHART SHOWING VARIATION OF LOT NUMBER VERSUS D/B RATIO FOR VARIOUS PLANTS

TABLE 14. COMPARISON OF DETAILS OF D/B RATIO FOR VARIOUS PLANTS

ID No.	A30	B10	C00	C15	D15
% RAP	**30**	**10**	**0**	**15**	**15**
Maximum D/B ratio	1.40	1.20	1.30	1.30	1.40
Minimum D/B ratio	0.90	0.60	0.80	0.90	0.60
Average D/B ratio	1.20	0.94	0.96	0.98	0.99
Average Standard deviation for D/B ratio	0.06	0.10	0.08	0.08	0.11
Number of tests results below 0.6	0	0	0	0	0
% tests results below 0.6	0.00	0.00	0.00	0.00	0.00
Number of tests results above 1.2	67	0	1	1	3
% tests results above 1.2	34.90	0.00	4.76	16.67	10.00

VMA

Figure 10 shows the variation of VMA with lot number for various plants. Also, Table 5 gives detail information of maximum, minimum and average amount of asphalt content for various plants. From the Table 5 it can be observed that 14% of test results of A30 plant were below the VMA test result conducted at the lab and no test results were below minimum VMA requirement of NJDOT, which indicate that the VMA is not affected by the percentage of RAP in the mix.

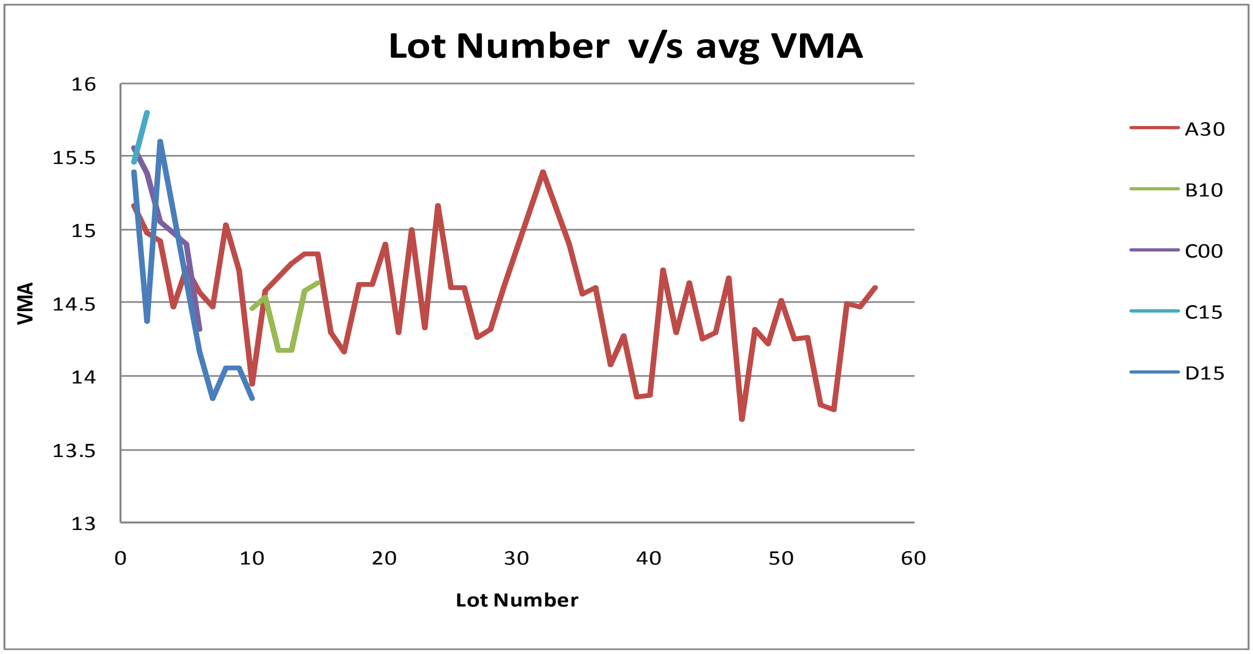

FIGURE 10. CHART SHOWING VARIATION OF LOT NUMBER VERSUS AVG. VMA FOR VARIOUS PLANTS

TABLE 15. COMPARISON OF DETAILS OF PERCENTAGE OF VMA FOR VARIOUS PLANTS

Plant	A30	B10	C00	C15	D15
% RAP	30	10	0	15	15
Maximum VMA (%)	15.70	15.10	16.00	15.80	16.10
Minimum VMA (%)	13.00	13.70	13.60	15.30	12.60
Average VMA (%)	14.50	14.43	15.05	15.63	14.42
Average Standard deviation for VMA (%)	0.38	0.32	0.39	0.07	0.73
Min VMA (%)	13	14	15	15	15
VMA in test result (%)	14.5	15.3	15.8	15.8	15.3
Number of tests results below min. VMA	0	3	7	0	21
% of tests results below min. VMA	0	11	33	0	70
Number of tests results below the VMA value presented in JMF	90	26	17	5	24
% of tests results below the VMA value presented in JMF	46	100	81	83	80

SUMMARY OF FINDINGS

From the above analysis it can be observed that dust to binder ratio is affected by the increase in RAP content but the other parameter like MC, AC, AV and VMA are less affected by the increase in RAP content. The higher amount of dust in HMA may cause either a rutting or cracking problem depending on whether the excess filler acts as an extender or as filler. One of the methods of controlling amount of fines in the HMA is through fractionation. Fractionation of RAP into two or more sieve will help control the amount of fines in the RAP mix.

In this analysis, data compared is from different plants, which have different quality control measures. Also availability data was limited. Hence this preliminary observation will lay the foundation for further detailed analysis.

FUTURE WORK

In next quarter QC data of the plant from North and South regional offices of the NJDOT will be obtained and analyzed.

REFERENCE

1. NJDOT specification 2007, Standard specification for road and bridge construction, division 900 materials, retrieved May 11, 2009 from http://www.state.nj.us/transportation/eng/specs/2007/spec900.shtm#s902
2. NJDOT specification 2007, Standard specification for road and bridge construction, division 400 pavements, retrieved May 11, 2009 from http://www.state.nj.us/transportation/eng/specs/2007/spec400.shtm#s40

RAP COATING STUDY

Table of Content

PROBLEM STATEMENT

There is an increasing demand to utilize higher percentages of Reclaimed Asphalt Pavement (RAP) in the construction of hot mix asphalt (HMA) pavements. Many states, including New Jersey, limit the amount of RAP that can be placed in the surface course. One of the primary reasons that RAP usage is limited is because the interaction between the RAP and the virgin materials remains largely unknown. Does the RAP binder blend completely with the virgin binder or is none of the RAP binder available for blending, supporting the “black rock” theory? The answer is somewhere in between these two extremes. Determining the amount of RAP binder that is available for blending with virgin binder is the primary focus of this study.

The state of New Jersey currently allow mixes to be designed assuming that all of the RAP binder is available for blending. An incorrect quantity of virgin binder may be added to the mixture because the quantity of binder in the RAP that is actually engaging with the virgin aggregate and binder is not known. If the amount of binder from the RAP that is available for blending is known then the amount of virgin binder that needs to add and the grade of the blended binder can be accurately determined.

GOAL

The goal of the research is to quantify the percentage of binder in the RAP that is available for blending with virgin binder under several mixing conditions.

PROOF OF CONCEPT

The amount of binder available for blending was evaluated by calculating the RAP binder that adheres to virgin aggregate. Three sets of mixtures comprising of 10, 25 and 40 percent RAP were mixed for 1, 3 and 5 minutes. Different percentages of ambient temperature RAP have been added to hot virgin aggregate and mixed for different lengths of time. The amount of RAP binder that is transferred is determined by weighing the virgin aggregate before and after mixing and determining the mass change.

RESEARCH APPROACH

The mixing of the virgin aggregate and RAP was conducted for three time intervals (1, 3 and 5 minutes) and three percentages of RAP (10, 25 and 40 percent). Local aggregates were sieved and only aggregates greater than the 1/2” sieve were used in the experiment. RAP was then sieved so that only material passing the #4 sieve was used. This gap gradation was used to ensure that the RAP and aggregate could be easily separated and weighed after mixing and conditioning. The virgin aggregate were then washed to remove any fines and dried to a constant mass. The virgin aggregate and RAP were weighed prior to and after mixing and conditioning. The difference in mass of the virgin aggregate before and after the mixing is the amount of binder transferred. The percentage transfer can be calculated by determining the percent binder in initial RAP sample using either ignition method or solvent extraction.

EXPERIMENTAL METHOD

The experimental procedure for this study is explained below:

- Sieve the aggregate to be greater than 0.5 in.
- Wash the aggregate.
- Dry the aggregate in the oven.
- Sieve the RAP to be less than #4 sieve.
- Measure the aggregate and RAP to the prescribed amounts (10% RP, 25% RAP and 40% RAP) and record them (It is important to accurately weigh them as this measurement will be used later in the experiment).
- Heat the aggregate to 350ºF in the oven.
- Heat the bucket and mixing arm to 350ºF.
- Mix each level of RAP for 1, 3 and 5 minutes, respectively.
- Place the bucket and mixing arm in the oven in between mixing (don't use them again until their temperature is 350ºF).
- Put the aggregate and RAP mix in the oven for 2 and ½ hours at 350ºF.
- Remove the aggregate and RAP mix from the oven; allow the aggregate mix to cool until it is able to be handled.
    - Separate the aggregate and RAP from the aggregate/Rap mix (be sure to remove the entire RAP from the aggregate as some of it will be attached).
- Weigh the aggregate and RAP that has been separated from the mix.

RESULTS

The results of the tests are shown in Table 1 below. The percentage transferred represents the percentage of binder transferred from the RAP to the virgin aggregate after mixing. It is calculated assuming the RAP used is composed of 5 percent binder. This percentage is used to compare results of the different samples because it is not dependent on the mass of RAP in the mix. Based on the preliminary results, the percent transferred greatly increases from 1 min to 3 min, and reduced as percentage of RAP increases. The results will be discussed in the following section.

TABLE 1. MASSES OF RAP AND VIRGIN AGGREGATE BEFORE AND AFTER CONDITIONING

Mixing Time		1 min	1 min	3 min	3 min	5 min	5 min
	RAP (%)	Agg.	RAP	Agg.	RAP	Agg.	RAP
Initial (g)	10	1801.2	200	1799.5	200	1799.9	200
Post mixing (g)	10	1802.6	192.2	1802.6	158	1802.8	153.8
Change (g)		+1.4	-7.8	+3.1	-42	+2.9	-46.2
% Transferred		**14**		**31**		**29**	
Initial (g)	25	1500.4	500	1500.7	500	1500.7	500
Post mixing (g)	25	1503.1	473	1509.5	478	1509.4	363.3
Change (g)		+2.7	-27	+8.8	-22	+8.7	-136.7
% Transferred		**10.8**		**35.2**		**34.8**	
Initial (g)	40	1200.1	800	1201.1	800	1199.8	800
Post mixing (g)	40	1201.5	786.7	1211.6	728.5	1211.4	694.2
Change (g)		+1.4	-13.3	+10.5	-71.5	+11.6	-105.8
% Transferred		**3.5**		**26**		**29**	

ANALYSIS AND DISCUSSION

This study was conducted using only one RAP source and only one replicate at each temperature and time. Based on the limited testing, the most RAP binder was transferred to the virgin aggregate mixture with 25% RAP. The reason is that 40% RAP mixture did not yield more transfer may be due to the lower temperature of the entire system. Since the RAP represents a larger percentage of the system, there is not as much hot aggregate available to heat the RAP sufficiently to mobilize the binder. The difference in results between 3 and 5 minutes is minor regardless of concentration of RAP. From Table 1 it can be seen that the increase in aggregate weight and the decrease in RAP weight do not match. This may be due to the following:

a. RAP was not dried prior to mixing. Most of the moisture in the RAP was removed during the conditioning period after mixing.

b. A split sample showed that the moisture content of the RAP was around 2.1% before mixing and the moisture was around 0.2% after conditioning.
c. Some of the RAP binder adhered to the bucket and mixing arm during mixing.
d. Some of the RAP binder coated other RAP particles.

The research team is in the process of revamping the experiment to account for some of these variables. The percentage of RAP binder that engages with the aggregate can be more precisely calculated if the percentage of binder that composes the RAP is known. The percentage of binder contained in the RAP can be determined by either the ignition method or a solvent extraction.

FINDINGS

The maximum percentage of binder that engaged with the virgin aggregate (based on the premise that the RAP is composed of 5% binder) was 35.2 %. The mixture composed of 40% RAP showed a decrease of binder transfer across the board compared to the mixture composed of 25% RAP caused by a decrease in mixing temperature because of the large percentage of unheated RAP in the mixture. This was especially evident for 40% RAP mix when the mixing time was 1 minute. Mixing time does not appear to affect the transfer of binder past 3 minutes as the results from 3 to 5 minutes for all concentrations of RAP are approximately the same.

FUTURE WORK

To-date only normal mixing conditions have been evaluated. Additional configurations will also be evaluated include increasing aggregate temperature, preheating of RAP prior to mixing.

FRACTIONATION OF RAP IN HMA PLANT

Table of Content

BACKGROUND

Separating RAP into two or more stockpiles helps in minimizing RAP variability and segregation of RAP particles. Stockpiles of different sieve sizes provide greater flexibility for adjusting RAP content for aggregate gradation (Copeland & Kvasnak, 2009). Determination of RAP binder content for different sieve sizes will help in predicting the contribution of RAP binder more precisely as per the assumption of working binder. This altogether can help to increase the amount of RAP used in the HMA which will then help to reduce the amount of virgin binder. Performance of fractionated RAP is expected to be better than unfractionated RAP (Copeland & Kvasnak, 2009). Fractionation of RAP in the plant has been carried out in the state like Texas, Alabama, South Carolina and Illinois. Following sections discuss the general HMA plant operation, RAP fractionation sizes, and additional plant requirement for RAP fractionation.

HMA PLANT OPERATION

BATCH PLANT

Figure 1 shows the general layout of the batch plant. In the batch plant, stockpiled aggregate stored into cold feed bins as per sieve size are fed into the aggregate dryer through conveyor belt. Extent of gate opening and speed of the conveyor belt control the amount of aggregate delivered to the aggregate dryer. Aggregate heated in the aggregate dryer are raised into screen deck through the hot elevator. In the screen deck aggregates are rescreened and stored into the hot bins. Aggregate and asphalt cement are blended into the pugmill in batches. This HMA is either stored into the storage silo or transported to the site through trucks (HMA Drum Plant).

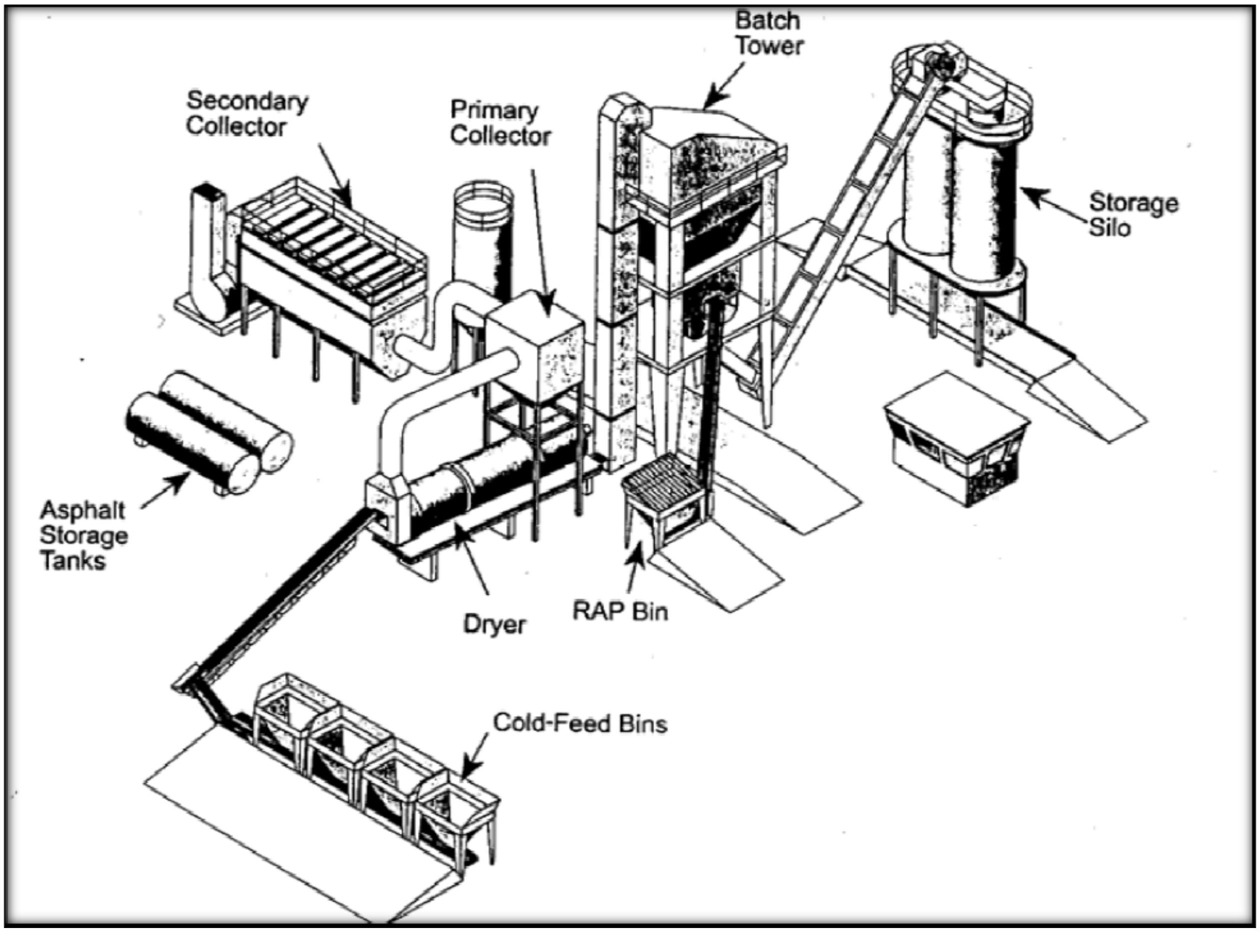

FIGURE 1. GENERAL LAYOUT OF THE BATCH PLANT (QA MANUALS)

Plants incorporating RAP into HMA may need to do some modification. Mainly the modifications are done to vent the steam. The steam is generated when hot dry virgin aggregate come in contact with relatively moist and cold RAP. Depending upon plant operation, the modification in the aggregate dryer, RAP cold feed bin and binder feeder are done. The batch plant operation methods for the RAP mix are given below (Kandhal & Mallik, 1997);

Method 1 – In this method hot aggregate and RAP are introduce at the boot of the hot elevator and screened and stored in hot bins.
Method 2 – In this method hot aggregate and RAP are introduce at the boot of the hot elevator and stored in separate hot bin without screening.
Method 3 – Maplewood method -In this method pre screened RAP is sandwiched hopper between superheated virgin aggregate from hot bins in weigh.
Method 4 – In this method RAP is weighed separately and dropped intermittently (20 to 30 second intervals) into the pugmill.
Method 5 – In this method, RAP material are heated separately and conveyed to separate heated storage bin with weigh hopper. RAP material is weighed separately and conveyed to pugmill.

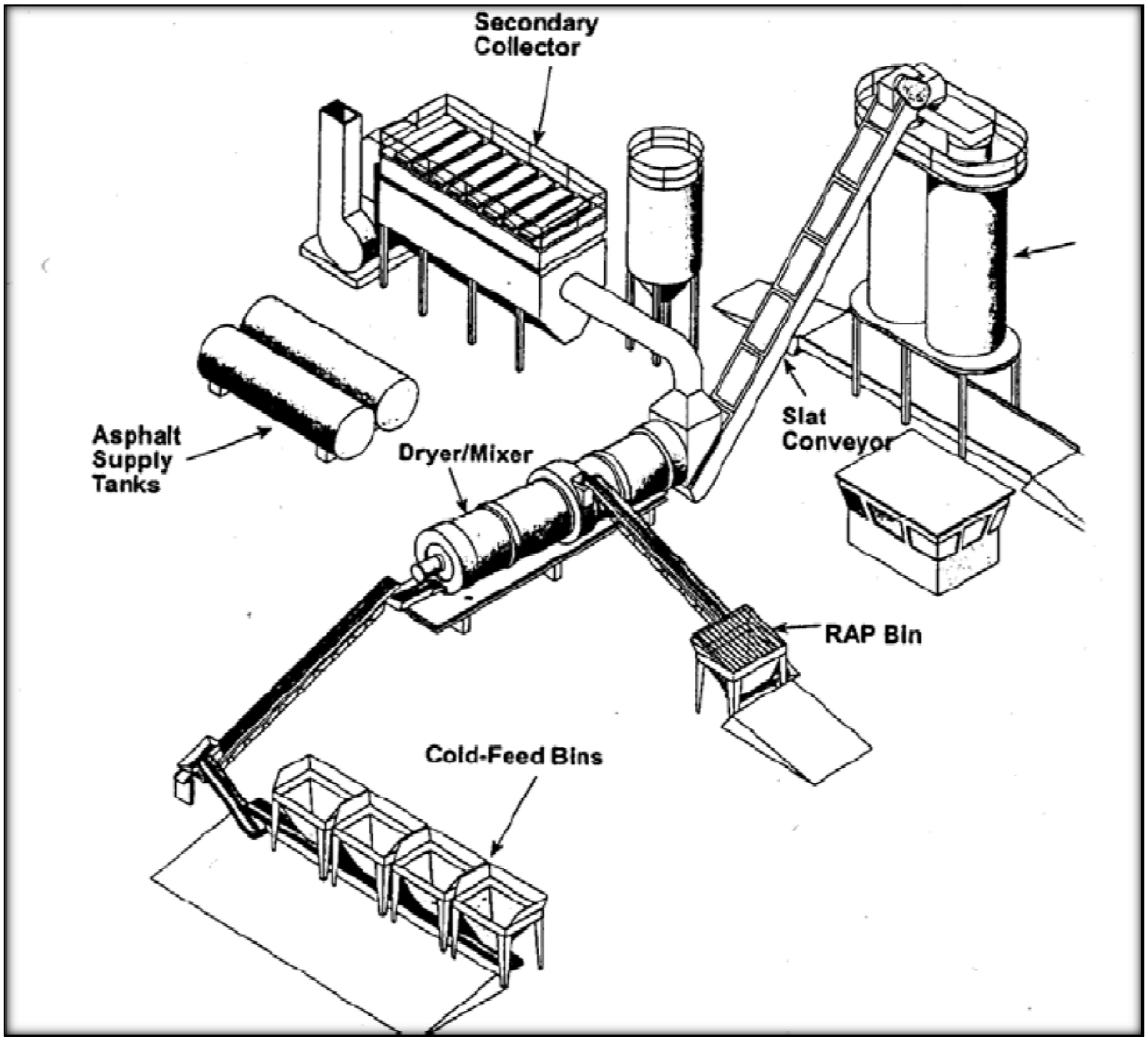

FIGURE 2. GENERAL LAYOUT OF THE DRUM PLANT (QA manuals)

Figure 2 shows the general layout of the drum plant. In the drum plant, stockpiled aggregate stored into cold feed bins as per sieve size are fed into the rotating drum through conveyor belt. In the rotating drum aggregates are heated and then mix with asphalt cement. There are basically two types of drum, parallel flow and counter flow. In parallel flow aggregate are fed into the drum at the end where burner is located and aggregate flow in the direction of the hot air steam. Whereas in counter flow aggregates are fed into the drum at the end opposite to the burner and it flow direction opposite to the hot air steam (HMA Drum Plant).

Similar to the batch plant, the drum plant also requires some modification in its operation to avoid "blue smoke" produced due to pouring RAP directly in contact with burner flame. Figure 3 shows different combination of center entry method. Different combinations are (HMA Drum Plant):

1. RAP added in counter flow dryer.
2. Parallel flow dryer with RAP added in continuous mixer.
3. RAP in drum mixer with counter flow drying tube.
4. Counter flow dryer with RAP added in continuous mixer.
5. RAP in counter flow drum mixer
6. RAP added in unitized dryer/mixer.

Among the plants visited plant A has single drum counter flow drum mixture, i.e. burner is at the opposite end of the drum where aggregate is fed. RAP is introduced in the drum near the burner where showering flight are absent. Such an arrangement of flight prevents RAP from coming in direct contact with the burner and avoids generation of blue smoke. RAP, virgin aggregate, sand and asphalt cement are mixed in the burner and delivered to the truck for transportation.

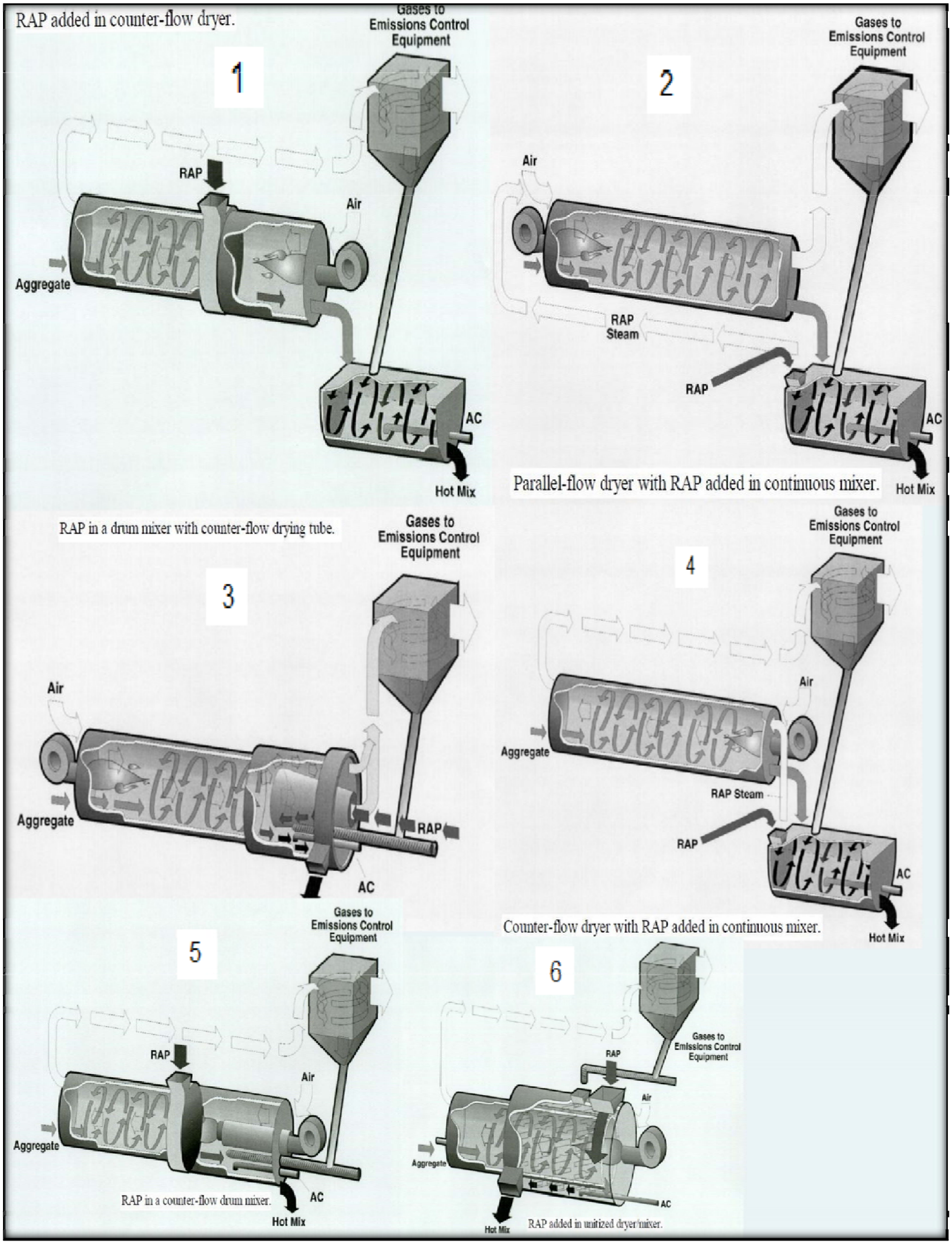

FIGURE 3. DIFFERENT COMBINATION OF CENTER ENTRY METHOD. (Kandhal & Mallik, 1997)

DIFFERENT RAP FRACTIONATION SIZES

Generally RAP is fractionated into coarse and fine fraction. Sieve sizes vary depending upon largest aggregate size in the HMA, state specification and individual contractor. The most common practice is to fractionate the RAP on the ¼" sieve size. In some cases, RAP is fractionated into three sizes such as oversize, coarse, and fine. For example, Diamond Material in DE successfully using high RAP and they fractionate into 3 sizes: +½", ½ - ¼", and -¼" (Copeland & Kvasnak, 2009).

PLANT REQUIREMENT

To fractionate RAP into different sizes plants require equipment for crushing and sizing RAP and cold feed bins for storing RAP. In the cold feed bins RAP of different sizes are stored in different bins and transfer to pugmill or drum through conveyor belt. The amount of RAP can be controlled by the speed of the conveyor belt and the extent of opening of cold feed bins. Requirement of such equipment incur initial additional cost on the plant for purchase, installation and maintenance (Copeland & Kvasnak, 2009).

SUMMARY OF FINDINGS

From the available literature it is found that fractionation of RAP into two or more sieve sizes reduces the variability of RAP which gives higher performance even for high percentage of RAP.

FUTURE WORK

Research is planning to visit the Diamond Material plant which does fractionation, to record the procedure and effort behind the fractionation.

REFERENCES

Copeland, A., & Kvasnak, A. (2009, May 7). Webinar on Design and Production of High Reclaimed Asphalt Pavement Mixes. USA.

HMA Drum Plant. (n.d.). Retrieved July 15, 2009, from www.pavementinteractive.org: http://pavementinteractive.org/index.php?title=HMA_Drum_Plant

Kandhal, P., & Mallik, R. (1997). Pavement Recycling Guidelines For State and Local Governments. Washington, DC: National Centre for Asphalt Technology.

QA manuals, I. (n.d.). Hot mix asphalt plant operation. Retrieved June 29, 2009, from www.in.gov: http://www.in.gov/indot/files/chapter_03(5).pdf